

# ANNALS OF SURGERY.

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AN EXPERIMENTAL CONTRIBUTION TO INTESTINAL SURGERY WITH SPECIAL REFERENCE TO THE TREATMENT OF INTESTINAL OBSTRUCTION.<sup>1</sup>

By NICHOLAS SENN, M.D., Ph.D.,

OF MILWAUKEE.

ATTENDING SURGEON TO THE MILWAUKEE HOSPITAL, PROFESSOR OF THE PRINCIPLES AND PRACTICE OF SURGERY AND CLINICAL SURGERY IN THE COLLEGE OF PHYSICIANS AND SURGEONS, CHICAGO, ILL.

THE most important, and, at the same time, the most popular topic for discussion among surgeons of the present day is intestinal surgery. The current medical literature is teeming with reports of cases, and at the meetings of almost every medical and surgical society, large or small, this subject comes up for discussion and occupies a liberal space and conspicuous place in their printed transactions. The unusual activity which has been manifested in all parts of the civilized world in the development of this, one of the most modern and aggressive departments of abdominal surgery, is sufficient evidence that the subject is comparatively new, and as yet imperfectly understood. A study of the literature of intestinal surgery must convince every unprejudiced mind that here, as in many other difficult problems in surgery, the positive knowledge which we have acquired rests almost exclusively on the results obtained by experimental research. Gunshot wounds of the abdominal cavity have been made the object of careful and patient experimentation by a number of enthusiastic surgeons, and the results obtained have laid the foundation

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for a rational method of treatment of these injuries, which has been eagerly accepted by all modern aggressive and progressive surgeons. The practical results which have been obtained thus far in the hands of a number of surgeons have been the means of saving a number of lives, which by the old conservative method of treatment would have been doomed to inevitable death from hæmorrhage or septic peritonitis. The numerous valuable practical suggestions for treatment of gunshot injuries of the intestines are the direct outcome of experiments on animals, and this, as well as the remarkable recoveries following gunshot wounds of the abdomen treated by laparotomy, have so firmly convinced the profession of the necessity of resorting to operative measures in such cases that few surgeons could be found at the present day who would be willing to trust to conservative treatment any case where positive, or only probable, evidences pointed towards the existence of a visceral injury of any portion of the intestine. While a decided advance has been made in the treatment of injuries of the intestinal tract, the operative treatment of intestinal obstruction still constitutes one of the darkest and most unsatisfactory chapters in the wide domain of intestinal surgery. The obscurity and uncertainty which cling to this subject are due to the difficulties which often surround an accurate diagnosis. At the same time we have every reason to believe that the appalling mortality which has so far attended the surgical treatment of intestinal obstruction is mainly due to late operations, and not infrequently to a faulty technique in the removal of the cause of the obstruction, and in the restoration of the continuity of the intestinal canal. An accurate anatomical or pathological diagnosis in such cases during life is often difficult, if not impossible, and when, as a *dernier ressort*, laparotomy is performed, and the surgeon is confronted by an unexpected condition of things, he is often in doubt as to what course to pursue, and frequently ends the operation by establishing an artificial anus. No one who has been forced to resort to this measure has left his patient with a feeling of satisfaction, as he must have been sadly impressed with the fact, that, at best, he has only been instrumental in relieving the urgent symptoms of the obstruction, while he has failed to re-

move its cause, and consequently also in restoring the continuity of the intestinal canal. A patient with an artificial anus is indeed an object of commiseration, as experience has sufficiently demonstrated how difficult it is in many instances to close the abnormal outlet, even after the cause of obstruction is subsequently removed or corrected spontaneously, without exposing him a second time to the risks of life incident to another abdominal section. If the causes which have led to the obstruction are of a permanent character, all attempts at closing the fistulous opening will, of course, prove worse than useless, and the patient is condemned to suffer from this loathsome condition the balance of his or her lifetime without a hope of ultimate relief. I believe I can safely make the statement without fear of contradiction that most of these unfortunate patients would prefer death itself to such a life of misery. The ideal of an operation for intestinal obstruction embraces the fulfilment of two principal indications:

1. The removal or rendering harmless of the cause of obstruction.
2. The immediate restoration of the continuity of the intestinal canal.

To meet the first indication the cause of obstruction must be found, its nature determined, and whenever advisable or practicable, it is removed, a step in the operation which may be very easy, or may demand a most formidable and serious undertaking, more especially in cases where the pathological conditions which have given rise to the obstruction are of such a nature as to constitute in themselves an imminent or remote source of danger, as, for instance, malignant disease or gangrene of the bowel from constriction. In all cases of inoperable conditions the cause of obstruction is rendered harmless as far as obstruction is concerned by establishing an anastomosis between the bowel above and below the obstruction by an operation which will be described further on.

Immediate restoration of the continuity of the intestinal canal should be secured in the operative treatment of all cases of intestinal obstruction, with the exception of inoperable cases of carcinoma of the rectum, but is most urgently indicated in cases of obstruction in the upper portion of the small

intestines and the colon, as the formation of an artificial anus in the former locality would prove a direct source of danger from marasmus by excluding too large a surface for intestinal digestion and absorption, while in the latter situation the cure of a fæcal fistula only too often proves an opprobrium of surgery. A careful perusal of the literature on the treatment of intestinal obstruction proves only too plainly the imperfection of this branch of surgery. The rules laid down in our text-books are often given with so much hesitation that it becomes impossible to apply them in practice. Opinions are so widely at variance that every surgeon finally acts upon the impulse of the moment and adopts a method which he deems appropriate for his case. It can be said that no uniformity of action exists, consequently the statistics which have been produced so far are of but little value from a practical standpoint. A rational and successful surgical treatment of intestinal obstruction, like other abdominal operations, can only be established upon a basis founded upon the results obtained by experimental investigation. In view of this fact it is astonishing that so little has been accomplished in this direction. I am convinced that accurate work of this kind will render essential information in the diagnosis of the obscure causes of obstruction, and will point out more clearly the indications for operative interference, while improved methods of operation will have to be studied exclusively in this manner. During the last 18 months I have made 150 operations on animals for the purpose of studying the effects of the principal varieties of intestinal obstruction, which were produced artificially; at the same time I have attempted to establish a number of new operations for the relief of certain forms of intestinal obstruction where it is impossible or inadvisable to remove the local conditions which gave rise to the obstruction. One of the greatest dangers in all operations for intestinal obstruction is the length of time required to perform the ordinary operations: hence it has been my object to simplify the operations, and thus by shortening the time diminish the danger from shock. All patients requiring an operation for intestinal obstruction are invariably in a condition not well adapted for prolonged operations, which necessitate the opening of the peritoneal

cavity and exposure of its contents to the cooling influences of the atmospheric air. An operation which can be completed in twenty minutes must certainly prove less disastrous to the patient than one requiring from one to two hours. A prolonged operation on the intestines is attended by two great risks: (1). Immediate, due to shock. (2). Remote, prolonged exposure to infection. Both of these dangers are diminished in proportion to the shortening of the time consumed in the operation, which is made possible by resorting to simpler measures, provided they are equally safe and efficient.

#### GENERAL REMARKS ON EXPERIMENTS.

With few exceptions the experiments detailed in this paper were made at the Milwaukee County Hospital, located at Wauwatosa, six miles from Milwaukee. I wish on this occasion to return my thanks to Dr. M. E. Connel, superintendent of the hospital, and his assistants, as well as to Dr. William Mackie, of this city, for valuable services rendered in my experimental work. As the main object of these experiments was not to show favorable statistics, but more for the purpose of studying the effect of different forms of intestinal obstruction and to establish new principles of treatment, the animals were not submitted to any special treatment before or after the operation; the diet was not restricted and no internal medicines were given. I pursued this course in order to bring the intestinal canal in the most unfavorable conditions for operative interference, so as to expose the operations to the severest test. Ether was used exclusively as an anesthetic. The abdomen was shaved, thoroughly washed with soap and warm water, and disinfected with a 1-1000 solution of corrosive sublimate or a two and a half per cent solution of carbolic acid. For the sponges the same solution of carbolic acid or a weaker solution of corrosive sublimate were used. The abdomen was covered by several layers of aseptic gauze, with a slit in the centre. Whenever division or incision of the bowel was made faecal extravasation was guarded against by compressing the bowel on each side by compressors made for this special purpose, or by constriction with an elastic rubber band. Experi-

ence showed that the latter method was preferable, as it proved less injurious to the tissues of the bowel, and afforded greater security against extravasation, while at the same time it proved less disastrous to the circulation between the points of compression. The rubber bands for this purpose should be about an eighth of an inch in width, rendered properly aseptic by prolonged immersion in a five per cent solution of carbolic acid, and can be readily applied by perforating the mesentery with an ordinary hæmostatic forceps at a point not supplied with visible blood vessels, and tied in a loop with sufficient firmness to obstruct the lumen of the bowel. Elastic constriction practiced in this manner prevents all possibility of extravasation, and does not interfere with the free manipulations of the operator, as is the case with clamps or the hands of an assistant, while the degree of compression that is necessary exerts no injurious effects on the vessels and tissues at the seat of constriction. Drainage was never resorted to, and the abdominal wound was always closed by deep interrupted sutures including the peritoneum. In all cases where partial or complete exventration was made necessary the bowels were kept covered with warm gauze compresses. In all cases where complete exventration became necessary, and where the bowels remained out of the abdomen for half an hour or more, a certain degree of shock was always noticed, and a number of animals died within a few hours after the operation, death being referable directly to this cause. For an external dressing we used iodoform ointment applied directly over the wound, and a compress of cotton, retained by a bandage, and a jacket, made of coarse cloth. As a rule the sutures were removed at the end of six days, when the wound was usually found healed by primary union.

#### I.—ARTIFICIAL INTESTINAL OBSTRUCTION.

In imitation of the more common forms of intestinal obstruction in the human subject, due to congenital malformation or pathological conditions, the following kinds of obstruction were produced on animals: (1) stenosis, (2) flexion, (3) volvulus, (4) invagination. It is a noteworthy fact that even in

cases where the obstruction was complete from the beginning, vomiting was moderate, and in some instances entirely absent. As vomiting constitutes one of the earliest and most conspicuous and persistent symptoms in most cases of intestinal obstruction in men, we can only explain its lesser intensity or complete absence in animals from the circumstance that animals suffering from this condition, as a rule, refuse all food and drink. As a rule, the tympanitis was also less marked than in the human subject.

# I. STENOSIS.

Circular narrowing of the lumen of the bowel was produced by excision of a semi-lunar piece of the intestinal wall and double suturing of the wound in a direction parallel to the intestine; and (2) circular constriction with bands of aseptic gauze.

## A.—PARTIAL ENTERECTOMY.

*Experiment 1.*—Dog, weight 39 pounds. A semi-lunar portion embracing half the circumference of the bowel removed from the convex surface, two inches above the ileo-cæcal valve. Wound closed in a longitudinal direction by Czerny-Lembert suture. The first two weeks the discharges from the bowels were fluid and dark in color, subsequently normal in color and consistence. Animal killed 36 days after operation. Body well nourished; abdominal wound indicated by a firm linear cicatrix. Omentum adherent at point of operation; lumen of bowel at point of operation reduced one-half in size; lumen of bowel above and below the contraction equal in size, showing that the stenosis had not furnished an obstacle to the passage of intestinal contents. A few of the sutures remain attached, their free ends floating in the bowel.

*Experiment 2.*—Large, full-grown cat. The same operation was performed on the concave side of the bowel about the middle of the ileum, a semi-lunar piece of the wall of the intestine with the corresponding mesentery being removed and the wound closed in a similar manner, which diminished the diameter of the lumen of the bowel to about one-eighth of an inch. It was noticed during the operation that the convex surface of the bowel over an area corresponding to the partial excision presented a cyanosed appearance. The animal died

on the fourth day after operation, and the whole segment of the sutured bowel was found gangrenous, but no fluid in the abdominal cavity.

*Experiment 3.*—Adult, large cat. In this case a segment of the ileum was emptied of its contents, and before cutting away a semilunar piece from the convex surface, a back-stitch, continuous suture was applied on the inner margin of the proposed line of incision, which left about one-third of the lumen of the bowel. After excision of the semilunar piece the margins of the cut surface were turned inwards and covered with serous surface by a continuous catgut suture. Several small passages occurred after the operation, but the animal died on the fourth day with symptoms of intestinal obstruction. The visceral wound was found healed, but the lumen had become so narrow from the inflammatory swelling of the tunics of the bowel that it was entirely inadequate for the passage of intestinal contents, and as a result of this obstruction the bowel had become considerably dilated above the point of operation.

REMARKS.—These experiments illustrate conclusively that in wounds of the convex side of the intestine, where from the nature of the injury transverse suturing is impossible, longitudinal approximation and suturing can be safely done, provided, at least, one-half of the lumen of the bowel can be preserved. If the stenosis is carried beyond this point there is great danger that the inflammatory swelling following the operation will still further narrow the tube and lead to the most serious consequences due to intestinal obstruction, and place the visceral wound in the most unfavorable condition for the healing process.

Experiment 2 shows the great danger of interference with the blood supply from the mesentery in longitudinal suturing of wounds on the concave side of the bowel, as such a procedure is invariably followed by gangrene of the corresponding segment of bowel on the convex side.

#### B.—CIRCULAR CONSTRICTION.

The following experiments were made to study the effect of circular constriction upon the circulation of the isolated constricted loop of bowel. In all cases where the constriction



was made with a gauze band this was tied with the same degree of firmness, so as to determine whether the same degree of strangulation would produce identical results.

*Experiment 4.*—Adult cat. A loop of bowel about the middle of the ileum, six inches in length, was tied with a band of aseptic gauze with sufficient firmness to cause slight congestion, but without interfering with a free arterial supply, as the arteries in the ligated portion continued to pulsate freely. The day after operation a few, small faecal discharges stained with blood. The cat died 48 hours after the operation. No rise in temperature was observed, and death was evidently caused by collapse from perforation. The loop of bowel showed gangrene on convex side equidistant from the point of strangulation, and a small perforation which had given rise to diffuse septic peritonitis. The whole visceral and parietal peritoneum were uniformly affected and the peritoneal cavity contained a considerable quantity of sero-sanguinolent fluid.

*Experiment 5.*—Large, adult cat. A loop of the ileum of the same length was tied in a similar manner and with same degree of firmness. The animal absolutely refused food until the eighth day. Rise in temperature second and third day. Only one faecal discharge on the second day. Killed eight days after operation. Abdominal wound completely united; no peritonitis. Four inches of bowel below the point of constriction showing that partial reduction had taken place. The gauze band was found completely covered with adherent omentum, and a thick layer of plastic lymph which formed a complete bridge connecting the intestine above and below the ligature. The ligated portion showed no evidence of defective circulation, and no ulceration underneath the ligature. The obstruction was complete as no fluid could be forced through the bowel, and in proof that the same condition existed during life, it was found that the bowel above the constriction was considerably dilated, while below the strangulation it was empty and contracted.

*Experiment 6.*—Large, Maltese cat. A loop of the ileum, six inches in length, tied in a similar manner. On the third day faeces stained with blood. On the same day the temperature, which had remained nearly normal until this time, rose to 105° F., and on the following day the animal died, having manifested symptoms of perforative peritonitis for 24 hours. Abdominal wound united; recent diffuse peritonitis. The abdominal cavity contained several ounces of sero-purulent fluid. Bowel above constriction distended with fluid contents, below the ob-

struction empty and slightly contracted. The greater portion of strangulated loop was found gangrenous and adherent to adjacent loops of bowel. Perforation had taken place in the middle of the loop on the convex surface, showing that gangrene had taken place first at this point and had extended from here towards the ligature.

*Experiment 7.*—Adult dog, weight 26 pounds. In this case an opening was made in the mesentery through which a loop of the small intestine, six inches in length, was pushed. With sutures this opening was made sufficiently small so that its margins produced slight strangulation. The dog remained perfectly well after the operation, and was killed on the twenty-second day. Abdominal wound completely healed. No signs of peritonitis. On searching for the seat of obstruction it was found that spontaneous reduction had taken place, the site of perforation in the mesentery being indicated by a recent cicatrix.

REMARKS.—The post-mortem appearances in these cases demonstrate clearly that the gangrene was not produced by the primary mechanical strangulation, but that it depended upon consecutive pathological changes in the loop or its vessels. In experiment No. 5, the primary strangulation was fully as great as in the preceding experiment, and yet gangrene did not take place, and we have positive proof that vascular engorgement in the ligated portion was less intense from the fact that partial reduction took place. In all cases where gangrene resulted, it must not have been from deficient arterial blood supply, but from an obstruction to the return of blood through the veins. If defective arterial blood supply had been the immediate cause of the gangrene, we would have found more constantly gangrene of the entire loop, while every specimen illustrated that gangrene always commenced at a point where the return of venous blood met with the greatest resistance, viz., on the convex surface in the middle portion of the loop. As in cases of hernia, or in any other form of intestinal strangulation, where a firm constricting band surrounds the loop of bowel, the danger of complete strangulation is increased if by the peristaltic action additional portions of the intestine are forced through the ring, and the immediate cause of the gangrene is always referable to obstruction to the return of venous blood which leads rapidly to œdema, complete stasis,

and moist gangrene in that portion where the venous circulation is most seriously impaired. Violent peristalsis under such circumstances always aggravates the existing conditions, and is often the precursor of symptoms of complete strangulation. In such cases opiates act favorably by arresting peristaltic action, and in so doing may avert gangrene by preventing the causes which otherwise would have led to complete venous stasis.

## 2. FLEXION.

As many instances are on record where flexion of the bowel constituted the cause of intestinal obstruction, this condition was artificially produced in animals either by making a partial enterectomy by removing a wedge-shaped piece from one side of the bowel, or, by bending the bowel upon itself acutely and fixing it in this position with catgut sutures.

*Experiment 8.*—Dog, weight 60 pounds. A wedge-shaped piece of the wall of the ileum was removed from the concave side with a corresponding portion of the mesenteric attachment, and after arresting the bleeding by tying several vessels with catgut, the wound was closed transversely by two rows of sutures. The excised piece measured one inch at its base, and the apex reached as far as the median line of the bowel. Immediately after excision, the convex portion of the bowel which had become acutely flexed by uniting the wound presented a livid, congested appearance, and after tying of the sutures the cyanosis increased. The area of disturbance of the circulation corresponded to the width of the base of the excised portion. About 14 inches from this place a similar piece was excised from the convex side of the bowel, and the wound closed in the same manner. At this point the flexion was only slight, the mesenteric portion forming the prominence of the curve. On the third day the temperature rose to 105.6° F., and the following day the animal died with symptoms indicative of perforative peritonitis. On opening the abdomen diffuse, general peritonitis was found with numerous adhesions. Gangrene and perforation were found on the convex side directly opposite the first operation. Second visceral wound closed and lumen of bowel at this point somewhat contracted, but permeable to fluids.

*Experiment 9.*—Large, adult cat. Removed from convex side of ileum a triangular piece measuring one inch at its base and the apex

reaching a little beyond the middle line of the bowel. Wound closed transversely by Czerny-Lembert sutures. After closure of the wound the bowel presented at point of partial resection an obtuse angle, the apex being formed by the mesenteric portion. The stools were bloody the second day after operation. The animal remained in excellent condition until it was killed, 43 days after operation. Adhesions of loops of small intestines to abdominal wound and of omentum and adjacent intestines at point of operation. The extent of flexion was found somewhat diminished, yet the concavity on convex side of bowel was well marked. Size of bowel above and below the operation was equal, showing that the flexion had not acted as a cause of obstruction. On opening the bowel a pouch-like bulging was found on the mesenteric side, which appeared to compensate for the narrowing caused by the artificial stenosis. Two of the deep sutures still remained attached to the inner surface of the bowel.

*Experiment 10.*—Adult, large cat. In this case a loop of the middle portion of the ileum, four inches in length, was acutely flexed in such a manner that the peritoneal surfaces of the convex side were brought in contact, and in this position the bowel was fixed by a number of fine catgut sutures. No symptoms pointing towards intestinal obstruction were observed, and the animal was killed 16 days after the operation. Wound was found completely united, and no signs of peritonitis. The angle of flexion had somewhat diminished, but otherwise the bowel adherent in position left after operation. The bowel presented no dilatation above nor contraction below the flexion, showing that complete permeability of the canal at the point of flexion was quickly restored.

REMARKS.—The partial excision on concave side of bowel in experiment No. 8 illustrates the danger of suturing wounds in this locality where the blood supply from the mesentery is likewise impaired, as gangrene of the remaining portion of the bowel is almost certain to take place. In all wounds on this side of the bowel more than half an inch in length, there is also another great danger which attends transverse suturing, viz., stenosis, which may become the cause of intestinal obstruction. As the small intestines naturally describe quite a strong curve with the concavity on the mesenteric side, closure of a wound involving this portion of the bowel gives rise to acute flexion which, at least, during the process of healing, must cause more or less obstruction until by yielding of the

opposite portion of the intestinal wall an adequate dilatation of the calibre of the tube has taken place. A considerable portion of the wall on the convex side of the bowel can be removed and sutured transversely until the bowel has been transformed into a straight tube, and a wound an inch in length will make only a slight flexion which furnishes no serious mechanical obstacle to the passage of the intestinal contents. In this connection the question arises: Does simple flexion, even if acute, without diminution of the lumen of the bowel, give rise to symptoms of obstruction? I have made numerous flexions when performing operations for establishing intestinal anastomosis, and in most instances satisfied myself by examination of the specimens that fluids passed them without great difficulty. If the bowel at the point of flexion remains free, certain portions of its wall will yield to pressure of the fluid intestinal contents, and gradually the lumen of the bowel will become restored. If, on the other hand, the entire circumference of the bowel at the point of flexion has become fixed and immovable by inflammatory adhesions or other pathological products, a compensating dilatation becomes impossible and the flexion becomes a direct and serious cause of obstruction.

### 3, VOLVULUS.

This condition, only another form of flexion, was experimentally produced by rotating a loop of intestine one and a half or two times around its axis and retaining it in this position by a number of fine sutures which were applied in places at the base of the volvulus, where fixation was most required.

*Experiment 11.*—Dog, weight 12 pounds. A loop of the ileum, eight inches in length, was brought out through a small incision and the tubes turned around their axis twice and the twist maintained by two catgut sutures. The constriction was sufficiently firm to cause considerable venous engorgement in the twisted loop. The dog manifested no unpleasant symptoms after the operation. The specimen was not obtained, as after a few days the dog ran away.

*Experiment 12.*—Medium-sized adult cat. In this case the volvu-

lus was made by twisting a loop of the ileum, about four inches in length, twice around its axis, and retaining it in this position by a number of fine silk sutures. Vomited several times during the first day. The first three days in taking the temperature in the rectum the thermometer when taken out was bloody. The first two days the temperature was normal, followed by an increase to 104.6° F. and 103.2° F. the two succeeding days, then it became normal. No constipation; appetite good throughout the whole time. Animal killed 22 days after operation. Abdominal wound completely united; no peritonitis. Volvulus remains as after operation, with the exception that where the bowel had been flattened by the twisting it had, at least, partially resumed its tubular form. Serous surfaces where approximated had become firmly adherent at point of constriction, size of bowel considerably diminished. The twisted loop contained liquid feces. Connecting the specimen with the faucet of a hydrant, water could be forced through, but on increasing the force of the current the peritoneum ruptured extensively in a longitudinal direction to point of partial obstruction.

REMARKS.—These experiments are interesting, inasmuch as the primary constriction produced in making and maintaining the volvulus which was sufficient to cause venous engorgement in the twisted loop must have been only of short duration, the disappearance of the effects of constriction being undoubtedly due to the gradual yielding of the sutured parts, while the faulty axis of the twisted loop was maintained by the sutures the circulation improved and remained in a sufficiently vigorous condition to adequately nourish the most distant portions of the volvulus. While it was found difficult to force fluid through the specimen of a volvulus, during life, propulsion of the intestinal contents by peristaltic action was carried on in a satisfactory manner, as the bowel above the volvulus was not dilated, and contained no abnormal amount of fluid, and the animal manifested no symptoms indicative of intestinal obstruction.

#### 4.—INVAGINATION.

The most frequent, and, from a surgical standpoint, the most important form of intestinal obstruction is invagination.

Leichtenstern and Leubuscher have made careful experimental studies to explain the mechanism and pathological conditions which give rise to this kind of intestinal obstruction, but in the following experiments this part of the subject was ignored, and the invaginations were made by direct manipulation. It was found impossible to make an invagination at any point, as long as the bowel was in a condition of contraction, consequently it was always found necessary to wait until the peristaltic wave had passed by, or to cause relaxation by firm pressure continued for several minutes. Usually, it was found easy to produce an invagination of the bowel, when in a state of relaxation, by indenting one side of the bowel, and pushing the pouch forward with a blunt instrument until the entire lumen of the intestine had passed into the section of the bowel below. After this was accomplished, further invagination was readily effected by manipulation consisting in pushing gently the intussusceptum and intussusciens in opposite directions. After I had learned by experience that disinvagination frequently takes place spontaneously, I resorted sometimes to suturing of the intussusceptum to the neck of the intussusciens for the purpose of maintaining the invagination. But even this expedient did not always succeed in retaining the malposition, as spontaneous reduction was observed in several of these cases.

*Experiment 13.*—Adult cat. The lower portion of the ileum and the cæcum and upper portion of the colon were drawn forward into an incision through the linea alba, and 5 inches of the ileum were pushed into the colon through the ileo-cæcal valve, when the parts were replaced and the abdominal wound closed. For six days the animal had a temperature from 102.6° to 105° F. and suffered from tenesmus. The stools contained mucus and blood. After the sixth day the symptoms due to invagination subsided, and were replaced by symptoms of peritonitis. The animal was killed 22 days after operation. Great emaciation; abdominal wound completely united; diffuse purulent peritonitis. The disease had evidently commenced in the ileo-cæcal region, as at this point the pathological changes were found most advanced. Complete spontaneous reduction of the invagination; colon greatly distended, and intensely congested.

*Experiment 14.*—Large, adult cat. Invagination was made in the lower part of the ileum. Length of intussusceptum three inches. For nine days the scanty faecal discharges contained mucus and at times blood. On the ninth day the temperature registered 105° F.; absolute refusal of food, and only occasional vomiting; death on the thirty-third day after invagination. Abdominal wound healed; small ventral hernia; no peritonitis. Apparently, the greater portion of the intussusceptum had disappeared by sloughing, and the subsequent healing process had produced an acute flexion at the neck of the intussusciens. Firm adhesions between peritoneal surfaces in the concavity of the flexion, nearly an inch in length. Above this point the intestine enormously dilated and distended with fluid contents. Below the obstruction the bowel was found contracted and empty. Water could not be forced through the obstruction from either direction. On slitting open the bowel in a longitudinal direction it was found that the lumen at the point of flexion was contracted to such an extent that only a fine probe could be passed. On the concave side of the flexion the mucous membrane presented a prominence marked by a number of longitudinal ridges. These folds had undoubtedly acted like valves in completely preventing the passage of intestinal contents, and later of the injection of water. Death in this case resulted from intestinal obstruction caused by cicatricial contraction after the sloughing of the invaginated portion of the bowel.

*Experiment 15.*—Adult cat. Two inches of the ileum were invaginated into the colon and fixed by two fine silk sutures at the neck of the intussusciens. For two days after the invagination the stools were scanty and contained mucus and blood. On the third day the abdominal cavity was re-opened by an incision along the outer border of the right rectus muscle, and the invaginated bowel drawn forward into the wound. No peritonitis. The bowel at point of operation was very vascular, and the neck of the intussusciens covered with plastic exudation. The sutures were removed and the rectum and colon distended with water for the purpose of effecting reduction. As soon as the colon had become thoroughly distended the adhesions gave away with an audible noise, and complete reduction followed in such a manner that the portion last invaginated was first reduced. After reduction had been accomplished the injection was continued to test the competency of the ileo-cæcal valve. As soon as the cæcum was well distended the fluid passed readily through the valve into the small intestines, showing that the valve had been rendered incompetent by the invagination. The force required to overcome the adhesions in



the reduction of the invagination was sufficient to rupture the peritoneal covering of the large intestines in three different places, the rents always taking place parallel to the bowel. The animal died on the following day with symptoms of diffuse peritonitis.

*Experiment 16.*—Ascending invagination in a cat. A few inches above the ileo-cæcal region the ileum was invaginated in an upward direction to the extent of two inches. At the time the invagination was made the intussusciens contracted firmly. In consequence of this a tear occurred in its peritoneal covering in a direction parallel to the bowel. The stools were few and scanty. On the fourth day the animal died of perforative peritonitis. Abdominal wound not united, but the peritoneal wound closed by omental adhesions. Spontaneous reduction of half an inch of the invagination had taken place. Reduction by traction was found impossible on account of firm adhesions about the neck of the invagination. Recent diffuse peritonitis caused by two perforations, one at the neck of the intussusceptum on mesenteric side, and the other a little to one side of this one and on proximal side of bowel. The perforation resulted from beginning sloughing of the invaginated portion of the bowel. About two inches above the invagination the bowel was acutely flexed towards the mesenteric side by recent firm adhesions. Flexion was undoubtedly caused by circumscribed plastic peritonitis and increased peristalsis.

*Experiment 17.*—Large, adult cat. Descending invagination of ileum to the extent of two inches in the upper portion of this part of the bowel. Second and third days the scanty discharges from the bowel bloody. Temperature from the second day after operation varied between 103.4° F. and 105.4° F. Death from perforative peritonitis on the seventh day after invagination. Abdominal wound united. Recent diffuse peritonitis from a perforation at the neck of the invagination on the mesenteric side. Gangrene of intussusceptum and partial separation which has again caused a sharp flexion of the bowel at the neck of the invagination. Above the seat of obstruction the bowel dilated and distended with fluid contents, below empty and contracted.

*Experiment 18.*—Young cat. Invagination of ileum into ascending colon to the extent of three inches. For a week after operation frequent tenesmus followed by mucous discharges mixed with blood. The temperature during this time varied from 102.6° to 105° F. After this the animal improved and was in good condition when killed fourteen days after operation. Abdominal wound united. No omental adhesions or peritonitis. Firm union between the serous surfaces.

No dilatation of bowel above seat of obstruction. Intussusceptum not gangrenous, its lumen about the size of an ordinary lead-pencil. It was found impossible to reduce the invagination by traction or by forcible injection of fluid from below. When the traction was increased the peritoneal surface of the neck of the intussusciens ruptured in a longitudinal direction.

*Experiment 19.*—Large, adult cat. Six inches of the ileum were invaginated into the colon. Frequent bloody discharges until the third day when the abdomen was reopened and the neck of the intussusciens exposed to sight so as to observe directly the mechanism of disinvagination by rectal injection of water. As soon as the colon was well distended the adhesions at the neck of the intussusciens began to give way, and complete reduction followed, as the adhesions gave away under the pressure from below. The abdominal wound was again closed and dressed in the usual manner. The animal recovered completely from the operation, and was killed twenty-four days after the first operation. Abdominal wound well united. In the ileo-cæcal region numerous adhesions around the portion of bowel which had been invaginated and subsequently reduced.

*Experiment 20.*—Invagination of colon into colon was commenced about the middle of the bowel and advanced as far as the cæcum. Second day bloody discharges from the bowels. Animal killed five days after operation. External wound united only on peritoneal side. Invagination completely reduced. Localized plastic peritonitis limited to the portion of the bowel which had been invaginated, otherwise peritoneum and intestines in a healthy condition.

*Experiment 21.*—Invagination of colon into colon to the extent of four inches in a cat. The subsequent symptoms only for a short time indicated the existence of invagination, which after they had subsided were followed by evidence of peritonitis. Death occurred on the nineteenth day after the invagination. Abdominal wound well united; diffuse purulent peritonitis; under surface of diaphragm covered with plastic lymph. Although sought for, no perforation could be found in the disinvaginated bowel, but as the peritonitis appeared to have started at the site of operation, it is probable that infection took place through the parietic walls of the disinvaginated bowel.

*Experiment 22.*—Same kind of invagination made in a cat as in the preceding case. For two days the stools were frequent, scanty, and contained mucus and blood. After this the animal remained in good condition until it was killed thirty-five days after the invagination. Abdominal cavity showed no trace of inflammation. The invagination

was completely reduced and the entire colon presented a normal appearance.

REMARKS.—With the exception of experiment No. 16, the invagination was always made in a downward direction. In the case of ascending invagination gangrene of the intussusceptum and perforation resulted in death from diffuse peritonitis on the fourth day after partial spontaneous reduction had taken place. In experiments, Nos. 15 and 19, both cases of ileo-cæcal invagination, complete reduction was effected by distention of the colon with water; in the first case the force required to accomplish this result was sufficient to produce multiple longitudinal lacerations of the peritoneal surface of the distended bowel, which undoubtedly were responsible for the death on the following day from diffuse peritonitis; while in the second case no such accident occurred, and the animal recovered, although the abdominal wound was re-opened for the purpose of observing the mechanism of reduction by this method of procedure. In one case of ileo-cæcal invagination, experiment No. 18, the intussusceptum remained *in situ* after the invagination, and became so firmly adherent with the intussusciens that even in the specimen reduction by traction was found impossible. In this case, although the lumen of the invaginated portion barely permitted the introduction of an ordinary lead pencil, no symptoms of obstruction were manifested during life, and the bowel above the invagination was not found dilated after death. In experiment No. 14, the sloughing of the intussusceptum led to cicatricial contraction of the bowel and flexion at site of invagination, conditions which resulted in death from obstruction twenty-three days after invagination. The great danger which attends sloughing of the invaginated portion is circumscribed gangrene and perforation of the intussusciens at the neck, and death from perforative peritonitis, as illustrated by experiments Nos. 16 and 17. Experiment No. 16 illustrates that ascending invagination, should it occur, is not more likely to be reduced spontaneously than the more common form of descending invagination. These experiments also demonstrate conclusively that the danger attending the invagination increases the higher it is located in

the intestinal canal, being greatest when it is situated high up in the tract of the small intestines, and gradually less as the ileo-cæcal region is approached. The ileo-cæcal form is less dangerous as spontaneous reduction is more likely to take place, and gangrene of the intussusceptum, when it occurs, does so after a longer time after firm adhesions about the neck of the intussusciens have formed, a condition which is well adapted to prevent perforation. Of the three invaginations of the colon, experiments, Nos. 20, 21 and 22, complete spontaneous reduction took place in all of them from the first to the fourth day, and in only one of them was the result fatal, in experiment No. 21, where purulent peritonitis, either from infection through the operation wound or, what is more probable, through the damaged wall of the colon occurred, and was the cause of death on the nineteenth day after the invagination. Experiments Nos. 15 and 19, prove both the danger and the utility of distention of the colon in cases of ileo-cæcal and colonic invaginations. As a rule, the longer the invagination has existed the firmer the adhesions, and consequently the greater the danger of relying too persistently on this measure in reducing the invagination. In resorting to this expedient in the reduction of an ileo-cæcal invagination, it is of the greatest importance to relax the abdominal wall completely by placing the patient fully under the influence of an anæsthetic, and to add to the distending force as much as possible by gravitation, the patient should be inverted and the injection should always be made very slowly and with requisite care to prevent rupture of the peritoneal coat by rapid over-distention. When the obstruction is located beyond the ileo-cæcal valve, no reliance can be placed upon this measure, as can be seen from the following experiments made to determine the

#### PERMEABILITY OF THE ILEO-CAECAL VALVE.

*Experiment 23.*—While completely under the influence of ether an incision was made through the linea alba of a cat, sufficiently long to render the ileo-cæcal region readily accessible to sight. An incision was made into the ileum just above the valve, and by gently retracting the margins of the wound, the valve could be distinctly seen; water was then injected per rectum, and as the cæcum became well dis-

tended it could be readily seen that the valve became tense and appeared like a circular curtain preventing effectually the escape of even a drop of fluid into the ileum. The competency of the valve was only overcome by *over-distention* of the cæcum which mechanically separated its margins, which allowed a fine stream of water to escape into the ileum. The insufficiency of the valve was clearly caused by great distention of the cæcum. That such a degree of distention is attended by no inconsiderable danger was proved by this experiment, as the cat was immediately killed, and on examination of the colon and rectum a number of longitudinal rents of the peritoneal coat were found.

*Experiment 24.*—In this experiment, a cat was fully narcotized with ether and while the body was inverted water was injected per rectum in sufficient quantity, and adequate force by means of an elastic syringe, to ascertain the force required to overcome the resistance offered by the ileo-cæcal valve. Great distention of the cæcum could be clearly mapped out by percussion and palpation before any fluid passed into the ileum. As soon as the competency of the valve was overcome, the water rushed through the small intestines, and having traversed the entire alimentary canal issued from the mouth. About a quart of water was forced through in this manner. The animal was killed and the gastro-intestinal canal carefully examined for injuries. Two longitudinal lacerations of the peritoneal surface of the rectum, over an inch in length, were found on opposite sides of the bowel.

*Experiment 25.*—This experiment was conducted in the same way as the foregoing, only that the cat was not etherized. More than a quart of water was forced through the entire alimentary canal from anus to mouth. The animal was not killed, and lived for eight days, but suffered the whole time with symptoms of ileo-colitis. A post-mortem examination was not made in this case, although the symptoms manifested during life leave no doubt that they resulted from injuries inflicted by the injection. It will thus be seen that in the three cases where fluid was forced beyond the ileo-cæcal valve, in two of them the post-mortem examination revealed multiple lacerations of the peritoneal coat of the large intestines, while the third animal sickened immediately after the experiment was made, and died from the effects of the injuries inflicted eight days later. The injection of water beyond the ileo-cæcal valve in the treatment of intestinal obstruction must therefore be looked upon in the light of a dangerous expedient and should never be resorted to.

[TO BE CONTINUED.]